State of New Hampshire
DEPARTMENT OF ENVIRONMENTAL SERVICES
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March 16, 2000

SUBJECT: Draft Residential Indoor Air Assessment Guidance Document March 2000 Revisions

Dear Colleague:

The New Hampshire Department of Environmental Services (DES) is pleased to enclose a copy of the revisions to the Draft Residential Indoor Air Assessment Guidance Document. The document was originally issued in October 1998, and contains recommendations for conducting indoor air assessments at residences that have been affected by volatile organic compound (VOC) vapors. The document was developed exclusively for the Waste Management Division Site Remediation Programs to assist DES staff and consultants when conducting residential indoor air assessments.

The revisions are included on the attached tables originally issued in the October 1998 version. There are changes to the screening levels for several compounds listed in Table 1 Residential Indoor Air Guidelines. Table 2 Recommended Sampling and Analysis Methods for Residential Indoor Air Assessments has eliminated the sampling requirement for N-Hexane and Volatile Petroleum Hydrocarbons (VPH). Updated tables from Appendix A Methodologies for Calculating the Residential Indoor Air Guidelines are also attached.

We welcome your continued comments on this document. Your input will help to ensure that subsequent revisions remain protective of public health and provide cost-effective assessment strategies based on current sampling and analysis methodologies.

If you have any questions, comments or suggestions you may contact me at the Waste Management Division at (603) 271-2989.

Sincerely,

Robin Mongeon, P.E.
Oil Remediation & Compliance Bureau

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Enclosures: Table 1 Residential Indoor Air Guidelines
Table 2 Recommended Sampling and Analysis Methods for Residential Indoor Air Assessments
Appendix A: Table A-1, Table A-2
cc: Frederick McGarry, P.E., WMD Chief Engineer
George Lombardo, P.E., ORCB
Gary Lynn, P.E., ORCB
David Larson, DHHS-BHRA
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Table 1: Residential Indoor Air Guidelines

NHDES Residential Indoor Air Assessment Guidance Document

Chemical	CAS No.	EPA Cancer Classification	Ref.	Screening (ug/m3)	Ref.	Acute (ug/m3)	Ref.
Acetone	67-64-1	D	A	2,829	H	61,800	B
Benzene	71-43-2	A	A	2.5	D	160	B
Bromoform	75-25-2	B2	A	21	E		
Bromomethane	74-83-9	D	A	4	B	190	B
Carbon Tetrachloride	56-23-5	B2	A	3.1	E	1,300	B
Chlorobenzene	108-90-7	D	A	4	C		
Dichlorobenzene, 1,2-	95-50-1	D	A	40	C		
Dichlorobenzene, 1,4-	106-46-7	C	C	3	E	4,800	B
Dichloroethane, 1,1-	75-34-3	C	A	10	C/J		
Dichloroethane, 1,2-	107-06-2	B2	A	2	E	810	B
Dichloroethylene, 1,1-	75-35-4	C	A	2	E		
Dichloromethane	75-09-2	B2	A	3.5	D		
Dichloropropane, 1,2-	78-87-5	B2	C	2.3	E	230	B
Dichloropropene, 1,3-	542-75-6	B2	A	2.5	D		
Ethylbenzene	100-41-4	D	A	200	A		
Ethylene dibromide	106-93-4	B2	A	3.8	E		
n-Hexane	110-54-3		A	40	A		
Methyl ethyl ketone	78-93-3	D	A	200	A		
Methyl isobutyl ketone	108-10-1			16	C		
Methyl tert butyl ether	1634-04-4		D	18	D	7,200	B
Naphthalene	91-20-3	C	A	5	D		
Styrene	100-42-5	B2	C	4.1	G		
Tetrachloroethane, 1,1,1,2-	630-20-6	C	A	5	D		
Tetrachloroethane, 1,1,2,2-	79-34-5	C	A	3.4	E		
Tetrachloroethylene	127-18-4	B2	C	3.4	D	1,400	B
Toluene	108-88-3	D	A	80	A	11,300	B
Trichloroethane, 1,1,1-	71-55-6	D	A	200	C	10,900	B
Trichloroethane, 1,1,2-	79-00-5	C	A	2.7	E		
Trichloromethane	67-66-3	B2	A	2.4	E	490	B
Trichloroethylene	79-01-6	B2	C	2.7	E	10,700	B
Vinyl chloride	75-01-4	A	C	1.3	E	1,300	B
Xylenes (mixed isomers)	1330-20-7	D	A	60	C	4,300	B

Conversion (sorbent columns): ug/m3 = ppbv of chemical detected * molecular weight of chemical / 24.45

A = EPA's Integrated Risk Information System (IRIS), January 1999.

B = ATSDR, Minimal Risk Level (MRL).

C = EPA's Health Effects Assessment Summary Tables (HEAST), 1997, 1993, 1991.

D = Background

E = Practical Quantitation Level (PQL) (TO-15).

G = Excess lifetime cancer risk (ELCR) of 1.0E-6.

H = DES screening level is based on the annual ambient air limit (AAL) found in ENV-A 1400.

J = BHRA decision: Classified as a Group C carcinogen, an additional uncertainty factor was applied to the RfC. Twenty percent of this value was chosen as the screening level.

TABLE 2
NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES
RECOMMENDED SAMPLING & ANALYSES METHODS FOR
RESIDENTIAL INDOOR AIR ASSESSMENTS

TYPE OF VOC RELEASED	INITIAL SITE INSPECTION FIELD SCREENING	POST INITIAL RESPONSE ACTION INDOOR AIR SAMPLING (1)		TIME INTEGRATED INDOOR AIR SAMPLING (1)	
		SAMPLE COLLECTION	TARGET ANALYTES	SAMPLE COLLETION	TARGET ANALYTES
Gasoline and similar weight products	Field Screening using PID/FID(2)	Tedlar Bag, Solid Sorbents(3) or Canister(4)	BTEX and MtBE	Minimum 4-Hour Sample using Solid Sorbents(3) or Canister(4)	BTEX and MtBE
No. 2, 4, 6 Fuel Oil Diesel and similar weight products	Field Screening using PID/FID(2)	Tedlar Bag or Solid Sorbents(3)	BTXE and Naphthalene(5)	Minimum 4-Hour Sample using Solid Sorbents(3)	BTEX and Naphthalene (5)
Non-Petroleum VOC's	Field Screening using PID/FID(2)	Tedlar Bag, Solid Sorbents(3) or Canister(4)	VOC's of Known Concern (6)	Minimum 4-Hour Sample using Solid Sorbents(3) or Canister(4)	VOC's of Known Concern (6)

VOC: Volatile Organic Compounds **PID/FID: Photoionization Detector/Flame Ionization Detector** **MtBE: Methyl-butyl ether**
BTEX: Benzene, Toluene, Ethylbenzene, Xylenes

Notes: (1) All laboratory results must be reported in units of ug/m^3 and be accompanied by the "Residential Indoor Air Sampling Form."
(2) On-site portable GC analysis, tedlar bag or solid sorbent sample collection with laboratory analysis may be used to supplement field screening during the initial site inspection.
(3) Thermal desorption from sorbent tubes using EPA Methods TO-1, TO-2 or TO-17.
(4) Stainless steel canisters using EPA Methods TO-14 or TO-15.
(5) Due to poor recovery of naphthalene observed when analyzing whole air samples from canisters, DES recommends using thermal desorption tubes at fuel oil sites.
(6) Contact the DES project manager for additional guidance.

Table A-1: Residential Indoor Air Guidelines

Chemical	CAS No.	EPA Cancer Classification	Ref.	Screening (ug/m3)	Ref.	Chronic (ug/m3) (non-carcinogenic)	Chronic (ug/m3) (carcinogenic)	Ref.	Intermediate (ug/m3)	Ref.	Acute (ug/m3)	Ref.
Acetone	67-64-1	D	A	2,829	H	30,900		B	30,900	B	61,800	B
Benzene	71-43-2	A	A	2.5	D		10	C	60	F	160	B
Bromoform	75-25-2	B2	A	21	E		76	C				
Bromomethane	74-83-9	D	A	4	B	5		A	60	C	190	B
Carbon Tetrachloride	56-23-5	B2	A	3.1	E		6	C	320	B	1,300	B
Chlorobenzene	108-90-7	D	A	4	C	20		C				
Dichlorobenzene, 1,2-	95-50-1	D	A	40	C	200		C	2,000	C		
Dichlorobenzene, 1,4-	106-46-7	C	C	3	E	800	12	C	1,200	B	4,800	B
Dichloroethane, 1,1-	75-34-3	C	A	10	C/J	500		C	5,000	C		
Dichloroethane, 1,2-	107-06-2	B2	A	2	E	810	3	A			810	B
Dichloroethylene, 1,1-	75-35-4	C	A	2	E		0.2*	E	79	B		
Dichloromethane	75-09-2	B2	A	3.5	D	3,000	40	A	3,000	C		
Dichloropropane, 1,2-	78-87-5	B2	C	2.3	E	4	4	A	13	C	230	B
Dichloropropene, 1,3-	542-75-6	B2	A	2.5	D	20	2*	C	14	B		
Ethylbenzene	100-41-4	D	A	200	A	1,000		A	1,000	C		
Ethylene dibromide	106-93-4	B2	A	3.8	E		0.4*	E		C		
n-Hexane	110-54-3		A	40	A	200		A	200	C		
Methyl ethyl ketone	78-93-3	D	A	200	A	1,000		A	1,000	C		
Methyl isobutyl ketone	108-10-1			16	C	80		C	800	C		
Methyl tert butyl ether	1634-04-4			18	K	3,000	106	H	3,000**	B	7,200	B
Naphthalene	91-20-3	C	A	5	D	3		A				
Styrene	100-42-5	B2	C	4.1	G	1,000	148	C	3,000	C		
Tetrachloroethane, 1,1,1,2-	630-20-6	C	A	5	D	1,000	11	C				
Tetrachloroethane, 1,1,2,2-	79-34-5	C	A	3.4	E		2*	E	2,700	B		
Tetrachloroethylene	127-18-4	B2	C	3.4	D	270	6	C			1,400	B
Toluene	108-88-3	D	A	80	A	400		A	2,000	C	11,300	B
Trichloroethane, 1,1,1-	71-55-6	D	A	200	C	1,000		C			10,900	B
Trichloroethane, 1,1,2-	79-00-5	C	A	2.7	E		5	C				
Trichloromethane	67-66-3	B2	A	2.4	E		4	C	240	B	490	B
Trichloroethylene	79-01-6	B2	C	2.7	E		17	C	540	B	10,700	B
Vinyl chloride	75-01-4	A	C	1.3	E		1*	E	77	B	1,300	B
Xylenes (mixed isomers)	1330-20-7	D	A	60	C	300		C	3,000	B	4,300	B

A = EPA's Integrated Risk Information System (IRIS), January 1999.
B = ATSDR, Minimal Risk Level (MRL).
C = EPA's Health Effects Assessment Summary Tables (HEAST), 1997, 1993, 1991.
D = Background
E = Practical Quantitation Level (PQL) (TO-15).
F = EPA Superfund Technical Support Center, provisional value, May 1995.
G = Excess lifetime cancer risk (ELCR) of 1.0E-6
H = DES screening level is based on the annual ambient air limit (AAL) in ENV-A 1400.
J = BHRA decision: Classified as a Group C carcinogen, an additional uncertainty factor was applied to the RfC.
Twenty percent of this value was chosen as the screening level.
K = Based on mid-point of median concentrations for hoes with and without garages.
L = Guideline based on BHRA derived cancer potency factor.
* = The risk based value is below or equal to the TO-15 PQL,
an alternate collection/analysis method should be considered.
** = MRL was lower than IRIS RfC, defaulted to the RfC value.

Table A-2.: Derivation of Screening Levels

Residential Indoor Air Screening Levels				CANCER			RfC			MRL			BACKGROUND		PQL (TO-15)		Screening Level
Chemical	CAS No.	EPA Cancer Classification	Molecular Weight (g/mole)	Ca Potency $(mg/kg)/day^{-1}$	ELCR (1E-6) (ug/m3)	Ref.	RfC (mg/m3)	20% (ug/m3)	Ref.	ug/m3	20 % (ug/m3)	Ref.	ug/m3	Ref.	ug/m3	Ref.	Basis
Acetone	67-64-1	D	58.08		-								17.5	D	4.8	H	G
Benzene	71-43-2	A	78.1	2.90E-02	0.3	B							2.5	E	1.6	H	Bkgd
Bromoform	75-25-2	B2	252.75	3.90E-03	2.1	B							2.5	E	20.7	H	PQL
Bromomethane	74-83-9	D	94.95		-		5.00E-03	1	A	19	4	C	0.5	E	1.9	H	PQL
Carbon Tetrachloride	56-23-5	B2	153.82	5.30E-02	0.2	B							1.6	E	3.1	H	PQL
Chlorobenzene	108-90-7	D	112.56		-		2.00E-02	4	B				1	E	2.3	H	RfC
Dichlorobenzene, 1,2-	95-50-1	D	147.01		-		2.00E-01	40	B				1	E	3.0	H	RfC
Dichlorobenzene, 1,4-	106-46-7	C	147.01	2.40E-02	0.3	B	8.00E-01	160	A	601	120	C	1	E	3.0	H	PQL
Dichloroethane, 1,1-	75-34-3	C	98.96		10	I	5.00E-01	100	B				0.5	E	2.0	H	RfC
Dichloroethane, 1,2-	107-06-2	B2	98.96	9.10E-02	0.1	A				809	162	C	0.5	E	2.0	H	PQL
Dichloroethylene, 1,1-	75-35-4	C	96.95	1.20E+00	0.01	B							0.5	E	2.0	H	PQL
Dichloromethane	75-09-2	B2	84.93	7.50E-03	1.1	A	3.00E+00	600	B				3.5	E	1.7	H	Bkgd
Dichloropropane, 1,2-	78-87-5	B2	112.99	6.80E-02	0.1	B	4.00E-03	0.8	A				0.5	E	2.3	H	PQL
Dichloropropene, 1,3-	542-75-6	B2	110.98	1.30E-01	0.1	B	2.00E-02	4	A	9	2	C	2.5	E	2.3	H	Bkgd
Ethylbenzene	100-41-4	D	106.16		-		1.00E+00	200	A				2.2	E	2.2	H	RfC
Ethylene dibromide	106-93-4	B2	187.86	7.60E-01	0.01	B									3.8	H	PQL
n-Hexane	110-54-3		86.18				2.00E-01	40	A	600	120	C	2.3	E	7.0	H	RfC
Methyl ethyl ketone	78-93-3	D	72.11		-		1.00E+00	200	A				21.1	F	5.9	H	RfC
Methyl isobutyl ketone	108-10-1		100.16		-		8.00E-02	16	B						8.2	H	RfC
Methyl tert butyl ether	1634-04-4		88.15	2.80E-03	2.9	J	3.00E+00	600	A	2524	505	C	18	K	7.2	H	Bkgd
Naphthalene	91-20-3	C	128.19		-		3.00E-03	0.6	A	10	2	C	5	E			Bkgd
Styrene	100-42-5	B2	104.16	2.00E-03	4.1	B	1.00E+00	200	A	60	12	C	0.5	E	2.1	H	ELCR
Tetrachloroethane, 1,1,1,2-	630-20-6	C	167.85	2.60E-02	0.3	B							5	E			Bkgd
Tetrachloroethane, 1,1,2,2-	79-34-5	C	167.85	2.00E-01	0.04	B							0.8	E	3.4	H	PQL
Tetrachloroethylene	127-18-4	B2	165.83	5.10E-02	0.2	B				271	54	C	3.4	E	3.4	H	Bkgd
Toluene	108-88-3	D	92.15		-		4.00E-01	80	A	3769	754	C	15	E	1.9	H	RfC
Trichloroethane, 1,1,1-	71-55-6	D	133.4		-		1.00E+00	200	B				3.5	E	2.7	H	RfC
Trichloroethane, 1,1,2-	79-00-5	C	133.4	5.70E-02	0.1	B							0.5	E	2.7	H	PQL
Trichloromethane	67-66-3	B2	119.38	8.10E-02	0.1	B									2.4	H	PQL
Trichloroethylene	79-01-6	B2	131.4	1.70E-02	0.5	B							0.4	D	2.7	H	PQL
Vinyl chloride	75-01-4	A	62.5	3.00E-01	0.03	B							0.5	E	1.3	H	PQL
Xylenes (mixed isomers)	1330-20-7	D	106.16		-		3.00E-01	60	B	434	87	C			2.2	H	RfC

A = Integrated Risk Information System (IRIS), January 1999.
B = Health Effects Assessment Summary Tables (HEAST), 1997, 1993, 1991.
C = Agency for Toxic Substances and Disease Registry (ATSDR), Minimal Risk Level (MRL).
D = Vermont Department of Health, Indoor Ambient Air Survey (12/21/91-12/20/92).
E = New York State Department of Health, August 1997.
F = Modified from Shah et al. 1988.
G = DES screening level is based on the annual ambient air limit (AAL) found in ENV-A 1400 of 2,829 ug/m3.
H = @ AIR TOXICS LTD., Folsom, CA
I = BHRA decision: Classified as a Group C carcinogen, an additional uncertainty factor was applied to the RfC. Twenty percent of this value was chosen as the screening level.
J = Guideline based on BHRA derive cancer potency factor.
K = Based on mid-point of median concentrations for homes with and without garages.

Draft Residential Indoor Air Assessment Guidance Document

Waste Management Division
Site Remediation Programs

October 1998

Draft
Residential Indoor Air Assessment
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SECTION TITLE **PAGE**

1.0 INTRODUCTION

The "NHDES Residential Indoor Air Assessment Guidance Document" herein after the Guidance Document, contains recommendations for conducting indoor air assessments at residences in New Hampshire where a release of volatile organic compounds (VOC) is affecting or likely to affect indoor air quality. The goal of the guidance document is to protect the health of residents in a timely cost-effective manner. The Guidance Document is designed to assist DES staff, consultants and responsible parties when conducting residential indoor air assessments. It provides guidance on field screening, methods for indoor air sampling and analysis, recommendations for when temporary relocation and/or initial response actions may be appropriate and how indoor air quality data should be evaluated to ensure that the health of residents is protected. The Guidance Document is based on current sampling and analysis methodologies, toxicology, and risk assessment information and may be periodically updated. Figure 1 provides a flow chart that outlines the main elements of a residential indoor air assessment.

The Guidance Document establishes Residential Indoor Air Guidelines (Table 1) for several VOCs that are intended to guide decision-making during initial response actions and continuing through site cleanup. The Residential Indoor Air Guidelines were established by the Department of Health and Human Services-Bureau of Health Risk Assessment (BHRA) considering potential human health effects, and do not consider odor thresholds. Therefore, VOC odors may persist after acceptable risk levels have been achieved. The Residential Indoor Air Guidelines are based on available toxicological data as detailed in Appendix A and are appropriate for residential exposure scenarios only. For exposure scenarios that are non-residential in nature, a site specific evaluation of the indoor air quality would be required to determine the potential risk to human health posed by VOC vapors. The guidance document does not address risks associated with exposure to VOC contaminated water supplies. This Guidance Document does not currently address semi-volatile organic compounds (SVOC), with the exception of naphthalene.

1.1 Background

DES adopted the Contaminated Sites Risk Characterization and Management Policy (RCMP) in September 1996 (revised in January 1998). In the RCMP, DES established groundwater categories, including groundwater category GW-2. GW-2 groundwater is considered to be a potential source of contaminant vapors to indoor air. The GW-2 standards presented in the RCMP are intended to trigger the examination of the indoor air exposure pathway. Where GW-2 standards have been exceeded in the vicinity of a residence, the recommendations provided in the Guidance Document may be used to assess the indoor air quality to determine the potential risk to human health posed by VOC vapors potentially migrating from contaminated groundwater into a home.

VOC vapors may affect residential indoor air quality following a residential fuel oil spill. Fuel oil spills can occur from overfills, leaking aboveground or under ground fuel tanks, sub-slab line leaks, accidents, or other spill/release scenario. The recommendations provided in the Guidance Document may be used to assess the indoor air quality following a residential fuel oil spill.

There are numerous variables that can affect the degree to which residents may be exposed to vapors from VOC releases. The magnitude of exposure and the ability to mitigate the exposure depends on factors such as:

- distance between the spill site and the residence;
- time of year when the spill occurred;
- time of year when the indoor air assessment is being performed;
- time since the spill occurred;
- amount of product spilled and recovered;
- physio-chemical characteristics of the VOC;
- air exchange rate in the residence;
- presence of a barrier between occupied spaces and VOC-contaminated media;
- foundation design and perimeter drainage systems;
- amount of time residents spend in the affected area(s);
- type, design and operation of HVAC system(s);
- roof and surface drainage systems; and
- hydrogeologic setting and meteorological conditions.

All of these variables combine to create site-specific conditions that can influence VOC vapor migration and movement in and around a home. Due to the dynamic nature of indoor air environments, it is important to collect representative indoor air samples for evaluating potential human health risks.

2.0 INDOOR AIR ASSESSMENT

A residential indoor air assessment may be required when a condition of concern is identified, which has the potential to impact indoor air quality in a residence caused by a VOC release. Conditions of concern may include but are not limited to the following:

1. GW-2 exceedance;
2. VOC odor complaint;
3. Fuel oil spill at a residence (free product); and
4. Elevated levels of VOC in soil gas adjacent to or in close proximity to a residence.

If any of these conditions are encountered, during any phase of the corrective action process, DES should be notified. Upon consultation with the DES, a decision to conduct a residential indoor air assessment shall be made. Sections 2.1 through 2.6 contain recommendations for conducting residential indoor air assessments where VOC vapors are affecting or likely to affect indoor air quality.

2.1 Site Inspection and Field Screening

An inspection of the residence should be conducted to identify the type and quantity of VOC released and the potential impact, if any, on indoor air quality. The goals of the site inspection, shall be to determine if temporary relocation of the residents is necessary and if initial response actions are needed to reduce VOC vapor concentrations in the home. If it is determined that VOC vapors are or have the potential to affect indoor air quality, DES shall be notified. Use the "Residential Indoor Air Sampling Form"(Appendix B) to describe the VOC release and general information about the residence.

It is possible that a VOC release can be cleaned readily without significant impacts on indoor air quality. In these cases, extended response actions and an indoor air assessment may not be warranted.

Rapid response is often critical at residences where there is potential of health effects due to VOC vapors. During the Site Inspection, indoor air screening shall be conducted to determine the need to perform initial response actions or recommend temporary relocation of the residents. Field screening instruments are valuable instruments because they can provide real-time concentration data for VOC vapors in air. Photoionization Detector (PID) or Flame-Ionization Detector (FID) instruments can be used to identify "hot spots," contaminant sources, and potential migration pathways, thus assisting in site reconnaissance and rapid decision making. However, PID/FID instruments should only be used as a field screening tool. Tedlar bags or solid sorbent sampling with rapid[1] laboratory GC analysis may also be used at the time of the initial site inspection to collect grab samples or time-integrated samples to supplement field screening results (See Appendix C for information on sample collection and analysis methodologies). More often than not, field screening is the only method used during the initial site inspection to monitor for the presence of VOC vapors. However, if indoor air samples are collected during the initial site inspection, analysis shall be for the target analytes listed in Table 2 “Recommended Sampling & Analysis Methods for Residential Indoor Air Assessments”.

Based on the results of the site inspection and indoor air screening and/or air sampling, the need for temporary relocation should be considered. Any recommendation to temporarily relocate residents should be made, when possible, after consultation with DES and/or BHRA. A recommendation to temporarily relocate residents may be influenced by but not necessarily limited to the following:

1. Evidence of a safety hazard as measured using a combustible gas indicator;
2. Sustained PID/FID readings above background in the living space; or
3. Air sample results (if available) for any of the target analytes listed in Table 1 exceed **Acute** levels in an inhabited part of the residence.

1 Tedlar bag samples should be analyzed within 72 hours of sample collection. Solid sorbent samples should be analyzed as soon as possible after sample collection preferably within 1 week.

2.2 Initial Response Actions

When conducting indoor air assessments at residences where VOC vapors are affecting or likely to affect indoor air quality, the goal of initial response actions shall be to reduce the levels of VOC vapors in the residence as quickly as possible by allowing the implementation of certain accelerated response actions to stabilize, treat, control, minimize or eliminate releases.

Initial response actions may include but are not limited to the following:

1. collection of soil gas, and/or indoor air samples;
2. installation of drainage controls;
3. covering, capping or restricting access to contaminated soils or other contaminated media;
4. free product recovery, groundwater treatment and/or containment;
5. removal of contaminated soils;
6. installation of vapor barriers, soil vapor extraction systems or sub-slab soil gas depressurization systems;
7. installation of ventilation fans;
8. installation of vapor phase carbon adsorption units; and
9. other appropriate site control measures

The source area, typically the basement, must be ventilated to the greatest extent possible to reduce the likely hood of accumulation of explosive vapors. The source area should also be closed off from the living space if possible. The home should be ventilated to the greatest extent possible during initial response actions to minimize VOC vapor concentrations in the living space.

Initial response actions to reduce VOC vapor concentrations would not be required if:

1. Indoor air sample results indicate target analytes are below the **Screening** levels listed in Table 1; or

2. An acceptable risk level exists using the chronic cumulative risk approach outlined in Appendix A. A chronic cumulative risk shall be calculated if **Screening** levels are exceeded for any of the target analytes listed in Table 1.

Initial response actions to reduce VOC vapor concentrations should be initiated for the following conditions:

1. Field screening indicates that VOCs are affecting the indoor air quality of the home;
2. Air sample results for any of the target analytes exceed **Acute** levels listed in Table 1, or
3. An unacceptable risk level exists using the chronic or intermediate cumulative risk approach outlined in Appendix A.

2.3 Post Initial Response Action Indoor Air Sampling

Post initial response action indoor air samples shall be collected to document indoor air VOC vapor concentrations following initial response action efforts. Indoor air sampling is required to determine if VOC concentrations present an immediate acute short term health risk, or potential health risk associated with longer term intermediate or chronic exposure durations. Post initial response action indoor air sampling should occur within seven days following completion of initial response actions, where VOC vapors have affected indoor air quality.

Samples should be collected in the "source area" near the VOC vapor source (most likely the basement where residential fuel oil spills often occur or where subsurface vapor migration pathways into the home exist such as sumps, utility conduits, and cracks in basement floors or walls). Assuming that the "source area" is not located in a part of the residence regularly used by occupants, a second sample should be collected in the main "living area". The "living area" sample should be collected in a room that is used regularly and that is closest to the source. This "living area" sample will provide a better estimate of the VOC vapor concentrations to which occupants are exposed. Additional sampling locations in the home may also be appropriate on a case by case basis.

Post initial response action indoor air samples may be grab samples or time-integrated indoor air samples. If the potential exists for acute short term risk, sampling and analysis should be completed as soon as possible after initial response actions. DES requires collection of time-integrated indoor air samples for evaluating chronic long term risk which may be appropriate following response actions (See Section 2.4 Time Integrated Indoor Air Sampling). Samples should be collected in a manner consistent with the "Residential Indoor Air Sampling Protocol" (Appendix D). Certain exceptions to the requirements of Appendix D may be appropriate on a case by case basis and should be discussed with DES.

Tedlar bag, solid sorbents, or canister sample collection with laboratory GC analysis may be used for collection and analysis of indoor air samples following initial response actions. Analysis should be completed as soon as possible after sample collection. The indoor air samples shall be analyzed for the target analytes listed in Table 2 "Recommended Sampling & Analysis Methods for Residential Indoor Air Assessments".

The indoor air sample results should be compared with DES Residential Indoor Air Guidelines listed in Table 1. Based on the results of the indoor air sampling, the need for temporary relocation of the residents, additional response actions and additional sampling shall be evaluated as described below.

A. Temporary Relocation of Residents

Based on the results of the indoor air sampling, the need for temporary relocation of the residents should be reconsidered. Any recommendations to temporarily relocate residents should be made, when possible, after consultation with DES and/or BHRA. A recommendation to temporarily relocate residents may be influenced by but not necessarily limited to the following:

1. Evidence of a safety hazard as measured using a combustible gas indicator;
2. Sustained PID/FID readings above background in the living space; or
3. Air sample results for any of the target analytes listed in Table 1 exceed **Acute** levels in an inhabited part of the residence.

The highest indoor air concentrations are generally found in the basement where spills often occur or where subsurface vapor migration pathways into the home exist. Relocation is not necessary if **Acute** levels are exceeded only in the basement and residents can avoid using the basement during initial response actions. Time integrated indoor air sampling as described in Section 2.4 is required prior to reoccupancy. DES does not recommend reoccupancy until concentrations meet the **Screening** levels or an acceptable risk level exists using the chronic cumulative risk approach outlined in Appendix A.

B. Additional Response Actions

If indoor air sample results indicate target analytes are below the **Screening** levels listed in Table 1, initial response actions to reduce VOC vapor concentrations are not required. If **Screening** levels are exceeded for any of the target analytes listed in Table 1 a chronic cumulative risk shall be calculated. If an acceptable risk level exists using the chronic cumulative risk approach outlined in Appendix A, no initial response actions are required to reduce VOC vapor concentrations.

Additional response actions should be initiated for the following conditions:

1. Air sample results indicate any target analytes exceed the **Acute** levels; or
2. An unacceptable risk level exists using the chronic or intermediate cumulative risk approach outlined in Appendix A.

The **Acute** levels listed in Table 1 are only protective for a short-term exposure duration of up to 14 days. Therefore where the **Acute** levels have been exceeded, response actions should be taken immediately and be designed to dramatically reduce VOC levels in the residence quickly, ideally within 14 days. An acceptable intermediate cumulative risk is protective of exposure durations up to 1 year. Therefore where the intermediate cumulative risk is unacceptable, response actions should be taken as soon as possible to reduce VOC levels in the residence quickly, ideally within 2 months. An acceptable chronic cumulative risk is protective of long- term exposure durations. Therefore where the chronic cumulative risk is unacceptable, longer term more permanent response actions should be taken to reduce VOC levels in the residence. An acceptable chronic cumulative risk level should be achieved within 1 year.

C. Additional Indoor Air Sampling

The collection of additional indoor air samples is recommended throughout the corrective action process, until concentrations meet the **Screening** levels or an acceptable risk level exists using the chronic cumulative risk approach outlined in Appendix A. The frequency of sample collection should be determined on a case by case basis and in consultation with the DES project manager.

2.4 Time-Integrated Indoor Air Sampling

DES requires collection of a minimum of one round of time-integrated indoor air samples for evaluating longer-term (chronic) health risks at sites where VOC vapors have affected residential indoor air quality. Additional sampling rounds using time-integrated indoor air sampling may be necessary on a case by case basis at the discretion of DES. A minimum 4-hour sampling period is recommended, to provide a better representation of exposure conditions. For the collection of 4-hour time-integrated samples, DES recommends the use of solid sorbents or pre-evacuated stainless steel canisters (See Appendix C for information on sample collection and analysis methodologies). The indoor air samples shall be analyzed for the target analytes listed in Table 2 “Recommended Sampling & Analysis Methods for Residential Indoor Air Assessments”. The analytical method used must be able to identify and quantify the target analytes and shall be capable of meeting the limit of detection (LOD) or practical quantitation limit (PQL) for the target analytes as listed in Appendix C Table 3.

Samples shall be collected from both the “source area” and “living area”as described previously in Section 2.3. Air sampling shall be conducted in accordance with the “Residential Indoor Air Sampling Protocol” (Appendix D), and by completing the "Residential Indoor Air Sampling Form" (Appendix B). All indoor air sample results submitted to DES and/or BHRA shall be reported in units of ug/m^3 and must be accompanied by a completed "Residential Indoor Air Sampling Form" (Appendix B).

Based on the results of the indoor air sampling, the need for temporary relocation of the residents, additional response actions and additional sampling shall be evaluated as previously described in Sections 2.3(1),(2),(3).

2.5 Indoor Air Assessment Complete - No Further Sampling Required

Before any residential indoor air assessment is considered complete and no additional indoor air sampling is required, a minimum of one round of time-integrated indoor air samples must be collected as described in Section 2.4. Additional sampling rounds using time-integrated indoor air sampling may be necessary on a case by case basis at the discretion of DES. The indoor air assessment will be considered complete if:

1. There are no ongoing active response actions implemented at the site, that were specifically implemented to reduce VOC vapors in the home (such as ventilation fans or soil vapor extraction systems); and

    a. Time-integrated indoor air sample results for target analytes are below the **Screening** levels for samples collected in both the "source area" and "living area", or

    b. Time-integrated indoor air samples from both the "source area" and "living area"indicate an acceptable risk level exists using the chronic cumulative risk approach outlined in Appendix A

Under certain situations, it may not be feasible to attain the **Screening** levels or an acceptable risk level using the chronic cumulative risk approach outlined in Appendix A due to site-specific factors. In such cases a site specific evaluation of long term risk to human health may be required. Contact BHRA for guidance in conducting any site specific evaluation of long term risk to human health. Where remedial technology is limited and can not achieve these indoor air quality goals, site specific activity and use limitations may be necessary to achieve or maintain protection of human health.

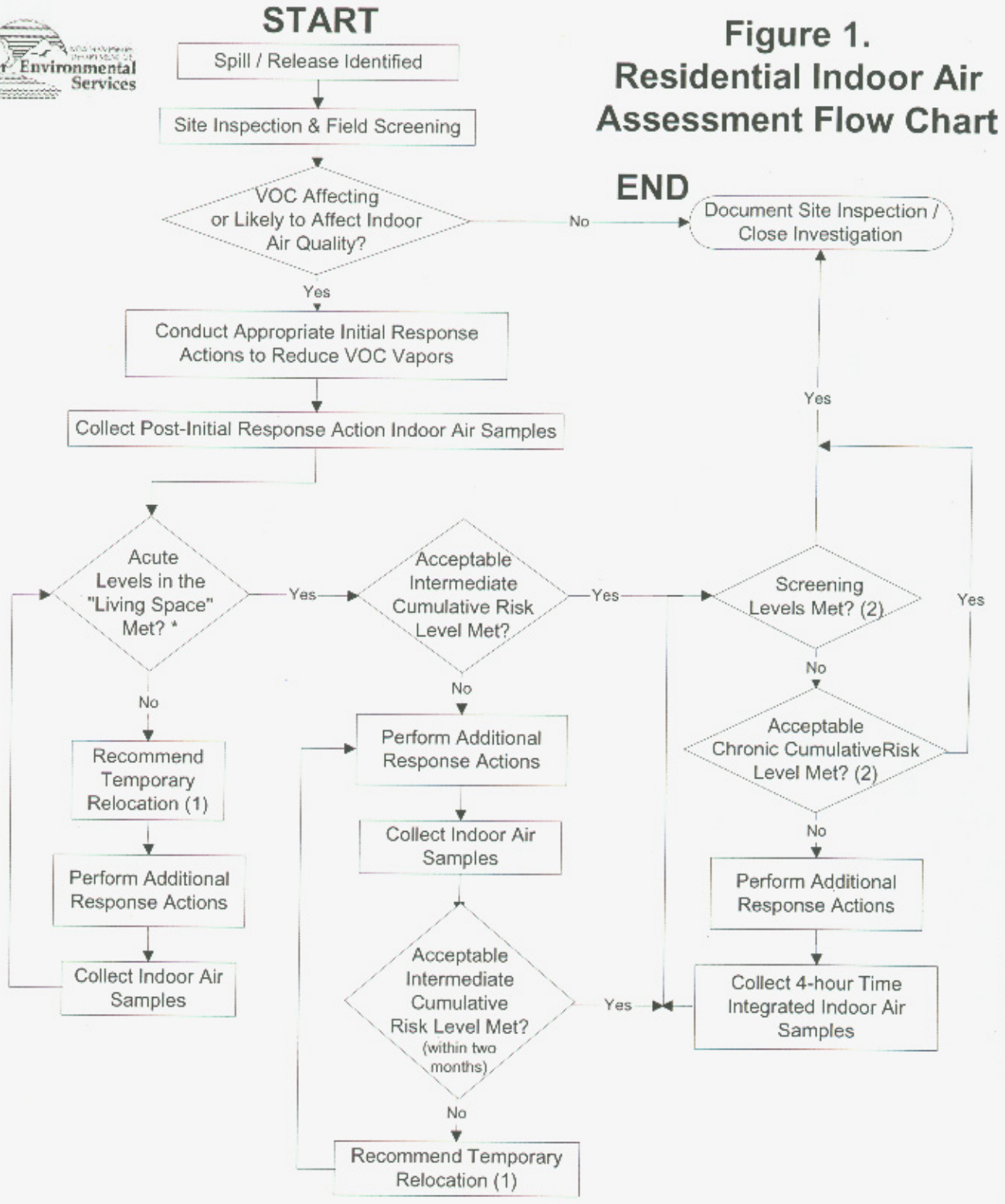
2.6 Documentation

DES requires documentation of all activities conducted during a residential indoor air assessment. The following is a list of items that shall be submitted to DES:

1. Residential Indoor Air Sampling Form(s),
2. Field Notes,
3. Description of Sampling Equipment, Analytical Methods
4. Laboratory Results with analytical detection limits
5. Chain-of-Custody forms,
6. Tabulation of all indoor air data,
7. All quality control sample results, including field blanks and duplicates,
8. Photographs and/or sketches of the house depicting sampling locations, and

9. Description of any initial response actions.

Figure 1. Residential Indoor Air Assessment Flow Chart



(1) Any recommendation for temporary relocation of residents should be made after consultation with DES and/or BHRA.

(2) A minimum of one round of time integrated indoor air samples meeting screening levels and/or chronic cumulative risk levels is required to close out the indoor air assessment.

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APPENDIX A

Methodologies for Calculating the Residential Indoor Air Guidelines

1.0. Purpose

This appendix provides the rationale for the derivation of chemical specific residential indoor air concentrations that are not anticipated to result in adverse human health effects for specific exposure durations. Only established screening levels and acute values are intended to be used on a one-to-one comparison basis. If any screening levels are exceeded at a site, the DES should be notified and a cumulative risk evaluation should be calculated for the chronic exposure duration, at a minimum, for each sampled floor of the residence. The BHRA recommends the calculation of the cumulative risk be performed by an individual with expertise in toxicology and knowledge of risk assessment practices. A Hazard Index (HI) or Risk Index (RI) exceeding unity (1) is considered unacceptable for potential cumulative adverse health effects. Section 8.0. provides guidance on the calculation of the HI and RI.

The BHRA assumes the indoor air sampling results are indicative of a well-mixed, uniform dispersion of target analyte(s) throughout the sampled floor of the residence. The BHRA also assumes Table 1 (located in the main body of this guidance) will be consulted only when residential indoor air quality samples have been collected according to recommended guidelines established in Appendix D. If conditions and/or procedures differ from those specified in this guidance, a discussion of changes or modifications should be included with any reports submitted.

2.0 Pathway Considerations

It is assumed that exposure is occurring by only the inhalation pathway. It is important to recognize that it is possible for exposure to be occurring from more than one pathway. For example, groundwater contaminated with volatile organic compounds (VOCs) may be used for showering and cooking, resulting in exposure by inhalation, absorption, and ingestion. When exposure from multiple pathways is suspected or a site-specific evaluation is considered, the BHRA should be consulted for acceptable exposure characterization parameters to determine the potential risk to individuals.

3.0. Approach

Four sets of residential indoor air guidelines have been established which include screening levels (section 4.0), chronic values (section 5.0), intermediate values (section 6.0), and acute values (section 7.0). Each set has been established to serve a specific objective in the course of evaluating the potential for an unacceptable risk to occupants from VOC exposure in a residential setting.

The first set of guidelines, screening levels (SLs), guide decision makers in determining if there exists the potential for an unacceptable risk resulting from VOC exposure, and if further assessment is warranted. When a SL is exceeded and a site requires further assessment, three distinct exposure duration guideline sets have been provided to allow for assessing risks posed for these specific periods. Each exposure duration set consists of chemical-specific values that represent an acceptable exposure concentration which is not anticipated to result in significant adverse health effects to individuals. The chronic and intermediate values are intended to be used in the assessment of potential cumulative risks from mixtures (refer to section 8.0). These guideline sets correspond to exposures lasting less than 14 days (acute), 15-364 days (intermediate), and 365 days or more (chronic) in length.

4.0. Screening Levels (SLs)

SLs have been derived with the intention of being inherently conservative to identify sites of concern that may require further assessment for possible remediation/mitigation and/or evaluation for unacceptable risk. If all detected concentrations of target analytes are below SLs in the initial sampling round using appropriate methodology (i.e. time integrated approach), the site need not require further assessment for potential risk posed. If a SL is exceeded for any single target analyte identified in Table 1, a chronic cumulative risk evaluation (HI and/or RI) should be calculated using all target analytes detected at the site using chronic values found in Table 1-A (refer to section 8.0). If the HI and/or RI are less than or equal to unity (1), then no further evaluation may be necessary.* When either a chronic HI or RI exceeds unity, further assessment of possible risks associated with an intermediate exposure duration is necessary.

The SLs were derived taking into consideration a number of factors related to a residential indoor air quality evaluation including background values, practical quantitation limits (PQL) of the analytical method, and risk-based criteria. For chemicals that have both a carcinogenic and non-carcinogenic value, separate risk-based values were calculated with the lower (more protective) concentration selected. The conservative risk-based value was then compared to the background and PQL values. The higher of these three values was then selected to represent the SL.

4.1. Residential Indoor Air Background Values

Under typical conditions, the residential indoor air environment can be expected to contain a wide variety of VOCs related to the construction material, consumer products, and activities occurring in the home. For these reasons, the concentrations of many VOCs are consistently higher in the indoor environment than in the ambient air outside the home. A study by the Environmental Protection Agency (EPA), covering six communities in various parts of the US, found indoor air levels of some contaminants up to ten times higher than those outdoors-even in locations with significant outdoor air pollution sources.[1] For purposes of evaluating risk attributable to a site under investigation, it is important to determine representative background

* At the discretion of the DES and BHRA, additional sampling may be necessary to characterize exposure conditions over time and/or for site closure.

concentrations of contaminants one would expect to be present in the home if there were no site related vapors present.

The State of New Hampshire has not conducted a detailed study to determine representative indoor air background concentrations of VOCs in New Hampshire residences. However, residential indoor air background concentrations have been characterized in other studies or surveys, and are available for New York[2], Vermont[3], and in a separate survey by Shah et al[4]. The BHRA has reviewed these databases and has adopted the central tendency (50th percentile) value for the living space from the New York database as representative of New Hampshire residences. This data set contains the most recently collected sampling results of the three sources, and also incorporated a detailed description of sampling methods, data analysis, and the most sensitive analytical methods at the time. If a background concentration for a target analyte was not identified in the New York study, the Vermont central tendency value was selected, followed by the Shah database. Table A-2 contains a summary of representative residential indoor air background concentrations for target analytes.

4. 2. Practical Quantitation Limits (PQLs)

PQLs used to derive these indoor air guidelines were based on EPA's method TO-15, which uses SUMMA canisters. PQLs of the analytical methods were considered relevant for samples collected and analyzed using a time-integrated approach, such as with EPA's method TO-15[5]. PQLs were not based on other methods commonly used to analyze indoor air quality such as the use of sorbent columns.

EPA method TO-15 involves the collection of air into a pre-evacuated passivated stainless steel canister and the direct analysis of the air sample. Sorbent column methodologies involve the adsorption of a mass of target analyte onto the sorbing media as the air passes through the column. The volume of air passing through the column can vary from site to site depending on site specific conditions and the professional judgment of the sample collector, thereby affecting the level of detection that can be achieved for any given sample. For this reason, the DES has chosen to include PQLs for only EPA method TO-15. Please refer to Appendix C for details regarding the various analytical methods. Table A-2 contains a summary of PQLs for target analytes achieved by EPA method TO-15.

4.3. Health Effects (Dose-Response Toxicity Information)

Dose-response information provides a quantitative evaluation of the toxicity data and allows for characterizing the relationship between the inhaled dose and the adverse health effect(s) in the exposed population. The scientific literature has been reviewed by various federal agencies (EPA, ATSDR) and for certain chemicals these agencies have derived and reported dose-response values. Examples of these values include the reference concentration[6] (RfC), cancer potency factor[7] (CPF), and inhalation minimal risk levels[8] (MRLs). The values published by the EPA and ATSDR have undergone peer review by panels of scientific experts.

Estimating the health effects from a mixture of chemicals is of particular concern since most sites usually contain two or more contaminants present at a time. When more than a single contaminant is present there is the potential for a diverse array of interactive effects. Such interactions can be in the form of additive, antagonistic, synergistic, or other interactive effects. Unfortunately, for most chemical mixtures there is a lack of toxicological data. In addition, when there is data available for mixtures, it is difficult to evaluate the effects of the infinite proportions that could be possible. Therefore, the dose-response values are based on experimental data from exposure to a single chemical, and do not consider the effects of exposure to chemical mixtures. To evaluate mixtures the BHRA assumes additivity of the target analytes detected at a site and accounts for this potential effect by the calculation of the HI and/or RI as described in section 8.0.

The concentration of a chemical in the air that is inhaled and the amount that reaches the circulatory system and eventually the target organ(s) to elicit the toxic effect is dependent on many variables. These variables include the physiological and metabolic differences in the regions of the respiratory tract, genetic differences between individuals, and the health status of the individual. In addition, the physiochemical properties of the inhaled chemical will influence the systemic or tissue dose, and ultimately the toxic effect. Because of the uncertainty involved with determining the tissue dose, the guidelines determined in this guidance are reflective of the acceptable concentrations in the residential indoor air prior to being inhaled.

4.3.1. Threshold Effects

For non-carcinogens, a range of exposures are believed to exist that can be tolerated with little likelihood of expression of an adverse health effect. The dose-response value derived by the EPA to protect against non-carcinogenic threshold effects is referred to as the reference concentration (RfC). The RfC is the human exposure dose at or below which deleterious non-carcinogenic effects are not anticipated to occur for a daily exposure over a lifetime. The reader is referred to Part A of the EPA's *Risk Assessment Guidance for Superfund (Vol. 1) Human Health Evaluation Manual*[9] and *Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry*[10] for a more detailed explanation of an RfC.

RfC values, which are EPA established chronic human health risk values, can be found on EPA's Integrated Risk Information System (IRIS). In addition, RfC and sub-chronic RfC values have been cited from EPA's Health Effects Assessment Summary Tables (HEAST). HEAST values consist of mostly provisional risk assessment information that has undergone review and has the concurrence of individual agency program offices. These values have not had enough review to have agency wide consensus approval. Please refer to the fiscal year 1997 HEAST[11] for a definition of the term "provisional". The Agency for Toxic Substances and Disease Registry's (ATSDR) Toxicological Profiles were also consulted and contain media specific information for individual chemicals from which minimal risk levels (MRLs) were derived. The MRL is an estimate of daily human exposure to a chemical that is likely to be without a substantial risk of harmful (non-cancerous) effects over a specified duration of exposure.

Considering most site exposure scenarios involve mixtures, and non-carcinogenic target analytes for characterizing a given site typically do not contain more than five compounds with the same critical effect, the BHRA has elected to consider one-fifth (20%) of the chronic dose-response value of a chemical to derive the SL. The SLs were generally based upon the source hierarchy of:

1.) RfC reported on IRIS2,
2.) most recent RfC reported on EPA's HEAST, and
3.) chronic inhalation MRL reported by the ATSDR.

Table A-2 contains a summary of the most recent chronic non-carcinogenic dose-response values reported by the EPA (RfC) and ATSDR (MRL) for target analytes.

4.3.2. Carcinogenic Effects

For a number of chemicals classified by the EPA as known (Group A), probable (Group B1, B2), or possible (Group C) human carcinogens, the EPA has calculated toxicity values referred to as cancer potency factors (CPFs)[*] . The CPF defines quantitatively the relationship between the dose and the response. Since risk at low exposure levels cannot be measured directly either by animal experiments or by epidemiological studies, a number of mathematical models and procedures have been developed for use in extrapolating from high to low doses. Models or procedures, which incorporate low-dose linearity are preferred when compatible with the information available. The EPA usually employs the linearized multistage procedure in the absence of adequate information to the contrary. When using data derived from animal studies, the CPF is an estimate of the upper 95th confidence limit of the slope of the dose-response curve extrapolated to low doses. Extrapolation is ordinarily carried out by first fitting a mathematical model to the observed data and then by extending the model from the observed range down toward risk expected at low exposure.

When available, a CPF based upon the inhalation route of exposure was used rather than an oral route CPF to evaluate carcinogenic substances. The source of CPFs were from EPA's IRIS and HEAST databases. IRIS is the most widely cited database for cancer dose-response values and in the past these values have been derived by assuming a low dose linear response. As EPA's new cancer guidelines go into effect, they will allow dose-response values to be based on threshold effects using mechanisms of action. As more information becomes available, the values in this guidance will be updated.

Conservative SLs were calculated for an excess lifetime cancer risk (ELCR) of one-in-one-million (1.0E-6) with exposure for twenty-four hours per day over an exposure duration lasting thirty years[12]. Default values for the calculation of carcinogenic SLs are provided in section 4.3.2.a. Table A-2 contains a summary of the SLs calculated based on an ELCR of 1.0E-6 for carcinogenic chemicals that have available CPFs.

[*] Not all Group C chemicals have cancer potency factors.

4.3.2.a. Calculation of Carcinogenic Risk for Screening Values

Conc. = (ELCR * BW * AT * CF) / (EF * ED * CPF * IR)

Parameter	Definition	Default Value
Conc.=	Chemical concentration	Determined (ug/m^3 per day)
ELCR =	Target Excess Lifetime Cancer Risk	1.0E-6
BW=	Adult body weight	70 kg[13]
AT =	Averaging time	25,550 days[14] (70 years * 365 days per year)
EF =	Exposure frequency	365 days per year
CF =	Conversion factor	1000 ug per mg
ED =	Exposure duration	30 years
CPF =	Cancer potency factor	Chemical specific (mg/kg-day)$^{-1}$
IR =	Inhalation rate	20 m^3 per day[15]

For chemicals that have both a carcinogenic and non-carcinogenic value, separate risk-based values were calculated with the lower (more protective) concentration selected. The conservative risk-based value was then compared to the background and PQL values. The higher of these three values was then selected to represent the SL.

5.0. Chronic Values (CV)

The CV is the level the BHRA has adopted or calculated which is not anticipated to result in adverse health effects from a single chemical for a chronic exposure duration lasting up to nine years. However, because contaminants are usually present as mixtures, the chronic values by themselves are not to be used as one-to-one comparisons with the detected concentration of target analyte(s). The chronic values listed in Table A-1 are intended to be used to calculate the HI and/or RI to evaluate the potential cumulative effect of exposure to a mixture of chemicals present at a site. In the cases where the exposure duration is expected to last longer than nine years, a site specific evaluation would be appropriate.

The BHRA considers an acceptable chronic risk level to be achieved when the cumulative risk (HI and/or RI) is less than unity considering all target analytes identified at a site. If the chronic cumulative target risk level is exceeded, but less than the intermediate target risk level, it is recommended that additional samples be collected monthly or less frequently (i.e. quarterly) as determined jointly by the DES and BHRA. If a site can not achieve conditions whereby the chronic target risk level is below unity within one year, the BHRA should be consulted for guidance to conduct a site specific evaluation.

The BHRA has established CVs for both non-carcinogenic and/or carcinogenic adverse health endpoints when information was available. The risk-based values were derived using the same informational sources as SLs, however, the percent of the RfC adopted, target risk level and exposure scenarios for carcinogens were adjusted to account for more realistic exposure assumptions as described in sections 5.1. and 5.2. Table A-1 contains a summary of the CVs.

5.1. Threshold Effects

For non-carcinogenic target analytes the BHRA has chosen to adopt 100% of the value listed in Table A-2 for the chronic value. For target analytes with both an EPA classification of "Group C" (possible carcinogen) and a chronic non-carcinogenic value, the BHRA has elected to divide the available non-carcinogenic value by an uncertainty factor between one and ten to derive the CV listed in Table A-1.

5.2. Carcinogenic Effects

For carcinogenic target analytes the BHRA has elected to derive values based on an excess lifetime cancer risk (ELCR) of one-in-one hundred thousand (1.0E-5) using an exposure duration of nine years[16]. To represent an appropriate high end daily exposure duration, the BHRA has selected a value of twenty-two hours per day based on survey results presented in the most recently published EPA Exposure Factors Handbook[17]. In summary, twenty-two hours per day was determined by averaging the 75th percentile cumulative number of minutes spent indoors in a residence reported for the Northeast Region of the United States of America, for the Winter season, and for individuals greater than sixty-five years of age. Please refer to section 4.3.2. for a discussion regarding informational sources for CPFs consulted in deriving CVs based on carcinogenic endpoints.

For Group C chemicals that have CPFs, a carcinogenic risk value was calculated and listed in Table A-1. Table A-3 contains a summary of the CVs derived to protect against carcinogenic endpoints.

5.2.a. Calculation of Carcinogenic Risk for Chronic Values

Conc. = (ELCR * BW * AT * HD * CF) / (ED * EF * ID * IR * CPF)

Parameter	Definition	Default Value
Conc. =	Chemical concentration (ug/m^3 per day)	-
ELCR =	Target Excess Lifetime Cancer Risk	1.0E-5
BW =	Adult body weight	70 kg
AT =	Averaging time	25,550 days (70 years * 365 days per year)
HD =	Hours per day	24 hrs per day
CF =	Conversion factor	1000 ug per mg
ED =	Exposure duration	9 yrs
EF =	Exposure frequency	365 days per year
ID =	Hours in home per day	22 hours per day
IR =	Inhalation rate	20 m^3 per day
CPF =	Cancer potency factor	Chemical specific $(mg/kg\text{-}day)^{-1}$

Table A-3: Carcinogenic Chronic Values.

Chemical	CAS No.	EPA Cancer Classification	Cancer Potency $(mg/kg/day)^{-1}$	Ref.	ELCR (1.0E-5) (ug/m3)
Benzene	71-43-2	A	2.90E-02*	B	10
Bromoform	75-25-2	B2	3.90E-03*	B	76
Carbon Tetrachloride	56-23-5	B2	5.30E-02*	B	6
Dichlorobenzene, 1,4-	106-46-7	C	2.40E-02	B	12
Dichloroethane, 1,2-	107-06-2	B2	9.10E-02	A	3
Dichloroethylene, 1,1-	75-35-4	C	1.20E+00*	B	0.2
Dichloromethane	75-09-2	B2	7.50E-03	A	40
Dichloropropane, 1,2-	78-87-5	B2	6.80E-02	B	4
Dichloropropene, 1,3-	542-75-6	B2	1.30E-01*	B	2
Ethylene dibromide	106-93-4	B2	7.60E-01*	B	0.4
Methyl tert butyl ether	1634-04-4		2.80E-3		106
Styrene	100-42-5	B2	2.00E-03*	B	148
Tetrachloroethane, 1,1,1,2-	630-20-6	C	2.60E-02*	B	11
Tetrachloroethane, 1,1,2,2-	79-34-5	C	2.00E-01*	B	2
Tetrechloroethylene	127-18-4	B2	5.10E-02	B	6
Trichloroethane, 1,1,2-	79-00-5	C	5.70E-02*	B	5
Trichloromethane	67-66-3	B2	8.10E-02	B	4
Trichloroethylene	79-01-6	B2	1.70E-02	B	17
Vinyl chloride	75-01-4	A	3.00E-01*	B	1

A = Integrated Risk Information System (IRIS), May 1998.

B = Health Effects Assessment Summary Tables (HEAST) 1997, 1993, 1991.

- = Indicates an inhalation cancer potency factor was available and used.

6.0. Intermediate Values (IV)

The IV or sub-chronic value corresponds to an exposure duration lasting from 15 to 364 days in duration. This exposure duration was selected to assess risks associated with exposure periods less than chronic but greater than acute in nature. These values are to account primarily for protection against intermediate non-cancer toxic endpoints. The intermediate values by themselves are not to be used as one-to-one comparisons with the detected concentration of target analyte(s). The intermediate values listed in Table A-1 are intended to be used to calculate the HI and/or RI to evaluate the potential cumulative effect of exposure to a mixture of chemicals present at a site.

The assessment of intermediate risk will largely depend on the time frame over which the results are averaged. To evaluate an intermediate risk the BHRA will typically evaluate an average concentration over a period of one and one-half (1.5) to two (2) months. After sampling, if an intermediate cumulative risk is exceeded, it is recommended that samples be collected bi-weekly to ascertain the residential indoor air concentrations of contaminants, and to verify that remediation/mitigation actions have been successful in lowering concentrations to below a level of concern for an intermediate duration.

When three successive rounds of sampling have been completed with the cumulative intermediate risk less than one for the mixture, samples may be collected less frequently as determined jointly by the BHRA and DES project manager. If sampling can not consistently demonstrate exposure to contaminants to be below the acceptable cumulative target intermediate risk level within a few months, temporary relocation should be considered and the BHRA should be consulted regarding a site specific evaluation. Table A-1 contains a summary of IVs.

6.1. Threshold Effects

For non-carcinogenic target analytes the BHRA has chosen to adopt 100% of the value listed by the referenced source. The priority for the source reference from which the intermediate exposure duration values was derived was typically an intermediate RfC value reported on HEAST, followed by an intermediate MRL reported by the ATSDR.

7.0. Acute Values (AV)

The AVs represent an exposure duration of fourteen days or less. The AVs listed in Table 1 are concentrations, which present an immediate potential risk for adverse health effects. If any target analyte is above it's listed value in the living space (and possibly other areas), the recommendation for residents to leave the home should strongly be considered at this time until remediation/mitigation actions are taken to lower the concentration(s) to within acceptable levels. Ideally, concentrations should be lowered to meet an acceptable chronic cumulative risk level prior to allowing residents to re-occupy a residence.

8.0. Calculation of the Hazard Index and/or Risk Index

If any SL is surpassed, the contaminants identified at a site should undergo a cumulative risk evaluation by individuals with expertise in toxicology and knowledge of risk assessment practices to characterize the potential health risk for the chronic and intermediate exposure duration. This evaluation can be conducted by the BHRA or appropriate individuals using the values provided in Table A-1 to calculate a Hazard Index (HI) and/or Risk Index (RI). A one-to-one comparison between the site related target analytes and the BHRA chronic and intermediate exposure values are not acceptable. Rather, the potential cumulative effect should be evaluated. The HI is to be calculated for non-carcinogenic target analytes with an EPA cancer classifications of "C", "D", or "E" with the same toxic endpoints. The RI is to be calculated for target analytes with EPA cancer classifications of "A", "B1", "B2", and "C"*. The following steps are recommended to calculate the HI and/or RI for <u>each sampled floor</u> of the residence for target analytes.

Step 1.) Determine that samples are acceptable for risk assessment purposes. This includes samples being collected according to Appendix B, appropriate detection limits of the analytical instruments have been met, quality control and quality assurance parameters have been completed, etc.

Step 2.) Record the measured concentrations of indicator compounds present on each floor of the affected residence.** If more than one sample is collected on a floor, the maximum measured concentration on each floor should be considered unless extenuating circumstances apply. Justification for not using the maximum concentration detected on a sampled floor should be included with any reports.

Step 3.) Separate the sampling results according to the floor where the samples were collected.

Step 4.) Separate the non-carcinogenic target analytes from the carcinogenic for each sampled floor. Several target analytes may require calculation under bothcategories. For example, methyl tert-butyl ether (MTBE) has both a non-carcinogenic and carcinogenic chronic value listed in Table A-1.

Step 5.) Obtain chronic and intermediate action levels for each target analyte provided in Table A-1.

Step 6.) Divide the measured concentration of each target analyte by its' respective value (chronic, intermediate). The result of this calculation is referred to as the Hazard Quotient (HQ) or Risk Quotient (RQ).

Step 7.) Total the HQ's for each target analyte with similar toxic endpoints for each exposure duration and sampled floor. This value is referred to as a Hazard Index (HI) for non-carcinogens for the floor where the sample was collected.

Step 8.) Calculate the Risk Index (RI) by summing the RQ's for each of the carcinogenic compounds.

Step 9.) A HI or RI greater than one indicates that the potential exists for adverse health effects from the mixture present at a site.

The reader is referred to Figure 1 in the main text portion of this document for guidance on appropriate response actions that correspond to the outcome of these duration specific risk estimates.

* In cases where there is an acceptable EPA derived cancer potency value available for this target analyte or an adjusted RfC.

** One-half the detection limit will be considered the concentration present when the target analyte is below the detection limit of the analytical method.

9.0 Volatile Petroleum Hydrocarbons

The BHRA requests the analysis of air samples for the aromatic and aliphatic C_5-C_8 and C_9-C_{16} fractions at petroleum impacted sites. This data is for informational purposes only. The BHRA is in the process of reviewing the scientific literature to determine the role of specific hydrocarbon fractions in the evaluation, remediation/ mitigation of a site.

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[3] Vermont Department of Health, Toxic Risk Assessment Program. *Indoor Ambient Air Survey Results, Yearly Sampling (Between 12/21/91 and 12/20/92).*

[4] Shah, Jitendra J., et al. *National Ambient Volatile Organic Compounds (VOCs) Data Base Update*. EPA/600/3-88/010a, March 1988.

[5] Winberry, W.T., Jr., et al., *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*, 2nd Edition. US EPA, Office of Research and Development, National Risk Management Research Laboratory, Center for Environmental Research Information, Cincinnati, Ohio, January 1997.

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[9] US EPA. Risk Assessment Guidance for Superfund: Volume 1- Human Health Evaluation Manual (Part A). EPA/540/1-89/002, December 1989.

[10] US EPA. Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry. EPA/600/8-90/066F, October 1994.

[11] US EPA. Health Effects Assessment Summary Tables: FY 1997 Update. EPA-540-R-97-036 PB97-921199, July 1997.

[12] US EPA. Exposure Factors Handbook. Office of Health and Environmental Assessment, Washington, D.C. EPA/600/8-89/043, March 1989. (National upper-bound time,90th percentile, at one residence).

[13] US EPA. Exposure Factors Handbook. Office of Health and Environmental Assessment, Washington, D.C. EPA/600/8-89/043, March 1989.

[14] Lifetime; by convention.

[15] US EPA. Exposure Factors Handbook. Office of Health and Environmental Assessment, Washington, D.C. EPA/600/8-89/043, March 1989. (Adult)

[16] US EPA. Exposure Factors Handbook. Office of Health and Environmental Assessment, Washington, D.C. EPA/600/8-89/043, March 1989. (National median time, 50th percentile, at one residence)

[17] US EPA. Exposure Factors Handbook, 1996. Table 14-129. Statistics for 24-hour Cumulative Number of Minutes Spent Indoors in a Residence (All Rooms).

APPENDIX B

Residential Indoor Air Sampling Form

DES Site #_____

DES Site Name _____

Address _____

_____

Residential Information

Residents Name: _____

Address: _____

_____

Telephone No: (H) (____)_____

(W) (____)_____

Describe the type of home (Multifamily/ Single family/ Condo/other)?

How many occupied stories does the home have? _____

Does the home have a (basement/crawl space/slab-on-grade/other)?_____

Is the basement used as a living area? _____

What type of foundation does the home have (field stone/poured concrete/concrete block /other)?

Describe the heating system and type of fuel used?_____

Does anyone residing in the home smoke? _____

Is there an attached garage? _____

Occupants Name, Age , Sex _____

Spill Information

Type of petroleum/VOC release? _____

When did the release occur? _____

What areas of the home have been impacted by the release? _____

Are there any odors? _____ If so, describe the odors:_____

Where can release odors be detected? _____

Sampling Information

Sampling Date: _____/_____/_____

Sampler Type: Tedlar Sorbent SUMMA

Analysis Method: TO-1 TO-2 TO-14 TO-15 TO-17 Other:_____

Consulting Firm: _____

Contact Person: _____

Telephone No.: (____)_____

Laboratory: _____

Telephone No.: (____)_____

Table 1.: Tedlar Bag/Sorbent Tube Sampler Information

Sample ID#	Floor	Room	Tube ID#	Pump ID#	Volume (liters)	Duration (minutes)	Comments

Table 2.: Canister Sampler Information

Sample ID#	Floor	Room	Canister ID#	Initial On-site Pressure*	Pressure* On-site Following Sample Collection	Pressure Received at the Laboratory

* Indicate pressure in units of inches of mercury.

Please provide a sketch of spill area and location of sampler unit(s).

Pre-sampling Inspection Inventory

List household items which may be considered potential sources of VOCs, such as paint cans, gasoline cans, gasoline powered equipment, cleaning solvents, furniture polish, moth balls, fuel tank, woodstove, fireplace.

Date of pre-sampling inspection: _____

Approximate time of inspection: _____

Table 3.: Pre-sampling Inspection Inventory

Potential VOC source	Present in the home (yes/no)	Removed 24 hours prior to sampling (yes/no/NA)	Location of source (i.e. room & floor)
paints or paint thinners			
gas powered equipment			
gasoline storage cans			
cleaning solvents			
furniture polish			
moth balls			
fuel tank			
wood stove			
fireplace			
perfumes/colognes			
other:			
other:			
other:			

Was the residence aired out prior to sample collection? _____

How long was the airing out process? _____

How long (hours) was the residence closed-up prior to collection? _____

Were response actions in effect while the samples were being collected? _____
windows open? Yes / No
ventilation fans? Yes / No
vapor barriers? Yes / No
vapor phase carbon treatment system? Yes / No
other site control measures? _____

Were samples collected in accordance with the Residential Indoor Air Sampling Protocol?_____

If not why? _____

Weather Conditions During Sampling

Outside temperature (F): _____

Prevailing wind direction: _____

Describe the general weather conditions(e.g. sunny, cloudy, rain):

Significant precipitation (0.1 inches) within 12 hours previous of the sampling event? _____

General Comments

Is there any information you feel is important related to this site and the samples collected which would facilitate an accurate interpretation of the indoor air quality?

_____

_____

_____

_____

Please submit this form with the sampling results.

APPENDIX C

Indoor Air Sampling and Analysis Methodologies

Many techniques are available for the sampling and analysis of volatile organic compounds (VOCs) in indoor air. Both portable and stationary instruments are available to collect instantaneous (grab) samples or time-integrated samples.

When preparing for a site inspection, careful planning is needed regarding which sampling equipment and procedures are appropriate for a given situation. Contributing factors including the nature of the VOCs of interest, environmental conditions and the sampling objectives must be considered. For residential indoor air sites, building characteristics, temperature, humidity and ventilation must also be taken into account. In addition, sampling methods should be appropriate for the living spaces as well as the basements of residences.

The following sections describe common sampling methods for both field screening and for procedures requiring fixed laboratory analyses. Also included is a section on analytical requirements for the determination of VOCs in indoor air.

FIELD SCREENING METHODS

Portable PID/FID Instruments

Portable PID/FID instruments have traditionally been used as general survey instruments at hazardous waste sites in particular for headspace analysis of soil and groundwater samples. These hand-held instruments employ either a photoionization detector (PID) or a flame-ionization detector (FID) for detection of vapors/gases. Due to their widespread use in environmental response at hazardous waste sites, portable PID/FID instruments have also been used in responding to situations where VOC vapors impact indoor air.

PID/FID portable instruments are valuable instruments because they can provide real-time concentration data for vapors and gases in air. PID/FID instruments can be used to identify "hot spots," contaminant sources, and potential migration pathways, thus assisting in site reconnaissance and rapid decision making toward a more refined sampling plan. However, these instruments should only be used as screening tools. Both the PID and FID portable instruments respond to a wide variety of vapors and gases and yield a non-specific total vapor/gas concentration that should not be considered absolute or representative of actual contaminant levels. Concentration data are only semi-quantitative for a mixture of gases due to the use of only one calibration compound.

These instruments also respond to many common interferences, such as humidity (both PID and FID instruments) and other voltage sources (PID instruments only), which can result in false positives and

anomalous high concentration readings. In addition, these instruments are restricted by high detection limits (typically on the order of 0.2 to 1 ppm) and do not provide sufficient sensitivity to differentiate normal from problematic petroleum vapors.

NHDES RECOMMENDATION FOR USE:

The PID/FID instruments should be used as field screening tools only. The PID and FID instruments should not to be used for the evaluation of potential risks associated with specific compounds.

Portable Gas Chromatography (GCs)

Portable GCs offer the advantage of real-time concentration data with compound separation, compound identification, and sensitive detection limits. Both short-term and long-term, time-integrated samples can be directly sampled and analyzed using a portable GC. Field GCs are more commonly used to analyze instantaneous (grab) samples, which can be injected via gas-tight syringes or pumped into the sample inlet port of the GC. In addition, field GCs can be used to obtain immediate results from grab or time-integrated samples collected using stainless steel canisters or Tedlar sampling bags. Sensitive detection limits on the order of 1 ppb can be obtained for many sample analytes.

DES RECOMMENDATION FOR USE:

Because data quality and usability obtained from portable GCs are highly dependent upon the operator's capabilities as well as instrument maintenance and calibration and environmental conditions, DES does not recommend the use of these instruments for the evaluation of potential risks associated with specific compounds.

SAMPLING METHODS REQUIRING LABORATORY ANALYSIS

Activated Carbon (e.g., ASTM Method D 3686-84)

Activated carbon is a solid adsorbent that has traditionally been used to monitor the workplace environment. Typically, in workplace scenarios where contaminant levels are high, small sample volumes are collected. Sample breakthrough is a potential problem with activated carbon for monitoring of low-level environments where larger sample volumes are necessary for analyte detection. Activated carbon has the disadvantage of requiring the use of organic solvents for compound removal; this can be a source of background contamination and the solvent extraction process results in higher detection limits. In addition, activated charcoal has a greater affinity for water, and retention of water in moist environments can prevent sample analysis.

DES RECOMMENDATION FOR USE:

Activated carbon may be used as a screening tool at appropriate sites; however, DES does not recommend the use of these adsorbents for the evaluation of potential risks associated with specific compounds.

Thermal Desorption Tubes (e.g., EPA Method TO-1,TO-2 and TO-17)

Thermal desorption from sorbent tubes has been used extensively for the collection of grab and time-integrated samples. Sorbent tubes can be used to sample large quantities of air, thus allowing for both the achievement of low detection limits for individual compounds, as well as for the capability to collect time-integrated samples. The sampling method consists of capturing the compounds of interest on the appropriate sorbent followed by release of these compounds, usually by thermal desorption, during laboratory analysis.

Areas of concern when using thermal desorption tubes to collect samples are sample breakthrough, background contamination of samplers and the fact that only one analysis run is possible per sample tube. Sample breakthrough is a problem particularly when time-integrated samples are collected. Sample breakthrough occurs when compounds are not retained by the collection medium during sampling. This often occurs if contaminant levels are high and large sample volumes are collected. The potential for breakthrough is a function of several variables including sample volume, pumping rate, VOC concentrations, temperature, sorbent type, and the size of the sorbent trap. Backup traps are often installed in series behind the primary trap to determine if sample breakthrough has occurred. Stringent tube cleaning, careful tube capping and storage procedures of the sorbent material are essential to obtaining reproducible and accurate results.

Commonly used commercial sorbents include Tenax®, Carbopack™, Carbotrap™, and Carbosieve™. Selection of the appropriate sorbent to use at a site depends on the contaminant of interest. A brief guide to the applicability of common sorbents is found in Table 1. Where a number of different sorbents fulfill the basic safe sampling volume criteria for the analytes in question, choose the one (or those) which are hydrophobic and least susceptible to artifact formation.

For 1/4 inch O.D. tubes, 50 mL/min is the theoretical optimum flow rate. However, negligible variation in retention volume will in fact be observed for pump rates varying from 5 to 200 mL/min. Pump flow rates above 10 mL/min are generally used to minimize errors due to ingress of VOCs via diffusion. Flow rates in excess of 200 mL/min are not recommended for standard 1/4-inch sample tubes unless for short term (e.g.10 minute) monitoring. Typical example pump flow rates include:

- - 16 mL/min to collect 1 L air samples in 1 hour
- - 67 mL/min to collect 4 L air samples in 1 hour
- - 25 mL/min to collect 6 L air samples over 4 hours

DES RECOMMENDATION FOR USE:

Thermal desorption tubes can be used to collect both grab samples and time-integrated samples. Samples should be taken in duplicate and observe all sampling precautions. Thermal desorption tubes are the recommended method to use for the minimum 4 hour time-integrated samples at fuel oil contaminated sites.

Stainless Steel Canisters (e.g, EPA Method TO-14 and TO-15)

Pre-evacuated passivated stainless steel canisters are recommended in EPA Method TO-15 for the collection of whole air samples. Pre-evacuated canisters are frequently used to collect time-integrated indoor air samples, but they can also be used to collect instantaneous (grab) samples.

Recent developments have greatly simplified canister set-up, and canisters are now very portable and easy to operate. In contrast to solid adsorbents, the collection and analysis of air samples using stainless steel canisters involves two simple steps: the collection of air in the canister and the direct analysis of the sample. Samples are typically collected under either pressurized or subatmospheric pressures. The most common sample volumes for canisters are 1 and 6 liters. One-liter canisters are generally used for grab samples or when high levels are expected; six-liter canisters are used for ambient air, risk assessment and time integrated samples.

One of the key advantages of canisters is that the sample volume is not limited by the breakthrough capacity as it is for solid sorbents. This capability of canisters is especially useful for sampling in areas of unknown contamination or when contaminant levels may vary. Furthermore, only a portion of the air collected in a canister is used for sample analysis, thus permitting multiple sampling runs if necessary. Multiple sample runs maybe necessary for a variety of reasons including instrument failure, blank carryover and sample confirmation.

Poor recoveries of naphthalene, 2-methylnaphthalene and phenol, which are semi-volatile compounds, are observed when analyzing whole air samples from canisters. This limitation must be kept in mind when deciding to choose a canister method at a site investigation.

DES RECOMMENDATION FOR USE:

Pre-evacuated passivated stainless canisters can be used for grab samples at most sites and for the minimum 4-hour time-integrated samples for gasoline or chlorinated solvents spill sites. Because of the low recoveries of naphthalene, canisters should not be used at fuel oil contaminated sites.

Tedlar Sampling Bags

Similar to stainless steel canisters, Tedlar sampling bags are an air displacement container. The bag is evacuated prior to use and air is collected by opening an inlet and using a pump for positive pressure. Tedlar sampling bags are more commonly used to collect instantaneous (grab) samples. Although Tedlar bags can be used for the collection of time-integrated samples, their usage is not recommended in part because there is a greater time for contact between the sample and the bag interior, which can potentially result in sample decomposition and sample loss. As with canister methods, poor recovery of naphthalene and other semi-volatile compounds is observed when analyzing from Tedlar bags.

DES RECOMMENDATION FOR USE:

Tedlar bags can be used for the collection of grab samples; laboratory analysis should be completed within 72 hours of the time the sample was taken.

LABORATORY ANALYTICAL METHODS

To obtain adequate sensitivity and accuracy, it is generally necessary to separate the sampling and analytical components of indoor air analysis. Laboratory gas chromatography (GC) or gas chromatography/mass spectrometry (GC/MS) are the analytical techniques for positive identification and precise quantitation of trace levels of volatile contaminants in air samples. Recommended methods of analysis are dependent on the nature of the contamination found at the site; suggested methods are included in Table 2. For final determination of site closure, a method with GC/MS detection must be used for analysis and minimum reporting detection limits must be reached. Table 3 shows acceptable reporting detection limits, which are achievable for a clean sample; limits for both a thermal desorption and for a canister method are given. For site closure, a laboratory report should include the following information: laboratory sample number, site location information, target analytes, analytical results, units of measure, reporting detection limits, date & time sampled, date & time analyzed, analytical method, volume of air collected, and, for canister methods, canister ID number and pressure of canister can at time of analysis or, for adsorption tube methods, tube ID number, air pump ID number and duration of sampling. Any modifications made to the method should be noted in the comment section or in the report narrative.

TABLE 1. GUIDELINES FOR SORBENT SELECTION

Sample Tube Sorbent	Approx. Analyte Volatility Range	Example Analytes
CarbotrapC® CarbopackC® Anasorb® GCB2	n-C_8 to n-C_{20}	Alkyl benzenes and aliphatics in volatility from n-C_8 to n-C_{16}.
Tenax® TA	bp100^o to 400^{o}C n-C_7 to n-C_{26}	Aromatics except benzene; Apolar components (bp>100^{o}C) and less volatile polar components (bp>150^{o}C).
Tenax GR	bp100^o to 450^{o}C n-C_7 to n-C_{30}	Alkyl benzenes, vapor phase PAHs and PCBs and as above for Tenax TA.
Carbotrap® CarbopackB® Anasorb® GCB1	(n-C) n-C_5 to n-C_{14}	Wide range of VOCs incl. ketones, alcohols, and aldehydes (bp>75^{o}C) and all apolar compounds within the volatility range specified. Plus perfluorocarbon tracer gases.
Chromosorb 106	bp 50^{o}C - 200^{o}C	Suits a wide range of VOCs incl. hydrocarbons from n-C_5 to n-C_{12}. Also good for volatile oxygenated compounds.
Porapak Q	bp 50^{o}C - 200^{o}C n-C_5 to n-C_{12}	Suits a wide range of VOCs including oxygenated compounds.
Porapak N	bp 50^{o}C - 150^{o}C n-C_5 to n-C_8	Specifically selected for volatile nitriles; acrylonitrile, acetonitrile and propionitrile. Also good for pyridine, volatile alcohols from EtOH, MEK, etc.
Spherocarb*	-30^{o}C - 150^{o}C C_3 to n-C_8	Good for very volatile compounds such as VCM, ethylene oxide, CS_2 and CH_2Cl_2. Also good for volatile polars e.g. MeOH, EtOH and acteone.
Carbosieve SIII*® Carboxen 1000*® Anasorb® CMS	-60^{o}to 80^{o}C	Good for ultra volatile compounds such as C_3, C_4 hydrocarbons, volatile haloforms and freons.

* These sorbents exhibit some water retention. Safe sampling volumes should be reduced by a factor of 10 if sampling a high (>90%) relative humidity.

** Significantly hydrophilic. Do not use in high humidity atmospheres unless silicone membrane caps can be fitted for diffusive monitoring purposes.

CarbotrapC™, CarbopackC™, CarbopackB™, Carboxen™ and Carbosieve SIII™ are all trademarks of Supelco, Inc., USA; Tenax is a trademark of Enka Research Institute; Chromasorb is a trademark of Manville Corp.; Anasorb is a trademark of SKC, Inc.; Porapack is a trademark of Waters Corporation.

TABLE 2. GUIDELINES FOR AIR METHODS

Method Number	Description	Types of Compounds Determined
TO-1	Tenax GC adsorption and GC/MS analysis	Volatile,nonpolar organics (e.g. aromatic hydrocarbons, chlorinated hydrocarbons, gasoline) having boiling points in the range of 80-200^{o}C.
TO-2	Carbon molecular sieve adsorption and GC/MS analysis	Highly volatile, nonpolar organics (e.g. vinyl chloride, benzene, toluene, gasoline) having boiling points in the range of -15^{o} to +200^{o}C.
TO-3	Cryogenic trapping and GC/FID or ECD analysis	Volatile, non polar organics having boiling points in the range of -10^{o} to +200^{o}C.
TO-4	High volume PUF sampling and GC/FID analysis	Organochlorine pesticides and PCBs.
TO-11	Adsorbent cartridge followed by High Pressure Liquid Chromatography (HPLC) detection	Formaldehyde
TO-13	PUF/XAD-2 adsorption with GC and HPLC detection	Polynuclear Aromatic Hydrocarbons (PAHs), fuel compounds
TO-14	SUMMA® passivated canister sampling with GC	Volatile organic compounds
TO-15	Passivated canister sampling with GC or GC/MS detection (performance based method)	Volatile organic compounds
TO-17	Adsorption onto sorbent or sorbent mix with GC or GC/MS detection	Volatile organic compounds, naphthalene, fuel compounds

TABLE 3. REPORTING DETECTION LIMITS

	METHOD T0-1	METHOD TO-15
ANALYTE	**LOD (ug)**	**PQL (ppbv)**
Acetone	0.05	2.0
Benzene	0.002	0.5
Bromoform	0.002	2.0
Bromomethane	0.007	0.5
Carbon tetrachloride	0.002	0.5
1,2-Dichlorobenzene	0.004	0.5
1,3-Dichlorobenzene	0.004	0.5
1,4-Dichlorobenzene	0.003	0.5
1,1-Dichloroethane	0.003	0.5
1,2-Dichloroethane	0.005	0.5
1,1-Dichloroethylene	0.003	0.5
Dichloromethane	0.002	0.5
1,2-Dichloropropane	0.002	0.5
cis-1,3-Dichloropropene	0.002	0.5
trans-1,3-Dichloropropene	0.002	0.5
Ethylbenzene	0.002	0.5
Ethylene dibromide	0.002	0.5
Hexane	-	2.0
Heaxchlorobutadiene	0.005	0.5
Methyl ethyl ketone	0.015	2.0
Methyl isobutyl ketone	0.015	2.0
Methyl-tert-butyl ether	0.005	2.0
Monochlorobenzene	0.002	0.5
Naphthalene	0.007	-
Styrene	0.002	0.5
1,1,1,2-Tetrachloroethane	0.002	-
1,1,2,2-Tetrachloroethane	0.002	0.5
Tetrachloroethylene	0.002	0.5
Toluene	0.002	0.5
1,1,2-Trichloroethane	0.002	0.5
Trichloroethylene	0.002	0.5
Trichloromethane	0.005	0.5

(Continued)

TABLE 3. REPORTING DETECTION LIMITS

	METHOD T0-1	**METHOD TO-15**
ANALYTE	**LOD (ug)**	**PQL (ppbv)**
Vinyl chloride	0.003	0.5
m/p-Xylene	0.002	0.5
o-Xylene	0.002	0.5

LOD= Limit of Detection
PQL= Practical Quantitation Limit

REFERENCES

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2. Heiger-Bernays, W.J., D. J. Vorhees, C. M. Long, *Trial Guideline for Protecting Residents From Inhalation Exposure to Petroleum Vapors*, Menzie-Cura Associates, Inc. for the State of Maine Department of Environmental Protection, September 1997.

APPENDIX D
Residential Indoor Air Sampling Protocol

Introduction

Indoor air sampling for specific volatile organic compounds(VOC) can be performed to assist in determining if a contaminant is adversely affecting indoor air quality in a home. In general, certain conditions should be met and certain procedures should be followed to ensure integrity of the test results, and to limit variables that may effect the success and interpretation of the data. This protocol is intended to ensure that air sampling data is collected in a consistent and useful manner following corrective action. The protocol outlines the steps to be followed when conducting indoor air sampling for VOCs in a residential setting. The resulting data obtained will provide a conservative indication of health risks posed to building occupants following corrective action.; however, DES understands that under emergency response actions it may not be appropriate to complete the 24 hour presampling inspection procedures outlined below.

Presampling Inspection

A presampling inspection shall be performed at least twenty-four hours prior to sampling in order to characterize the structure, layout, and physical conditions of the home under evaluation. In addition, the inspection will allow for the identification of potential sources of VOCs that may affect or interfere with the indoor air test(complete the Residential Indoor Air Sampling Form). If the target VOCs are petroleum-related, interfering sources include: gasoline cans, gasoline powered equipment, paints, and cleaning supplies containing petroleum distillates. If the target VOC is non-petroleum (such as tetrachloroethylene) other products or conditions, which may be sources of these compounds such as recently dry cleaned clothes should be identified. Removing potential sources of VOCs from the indoor environment prior to testing is the most effective means of reducing interferences. **The inability to eliminate potential interferences may be justification for not sampling.** If samples are collected and potential interferences were not eliminated 24 hours prior to sample collection, DES and/or BHRA will not be able to effectively evaluate the potential risks associated with the spill.

Once the interfering sources have been removed, aggressive ventilation must be completed prior to testing to eliminate residual contamination from the interfering sources. **Twenty-four hours or more prior to sampling, the house shall be ventilated by opening windows and doors for a period of 10 to 20 minutes.** The primary objective of the indoor air test is to obtain a worst-case representative sample that provides a conservative indication of the health risk posed by the VOC spill/release to the occupants. Such worst-case conditions may include times of high groundwater levels with VOC contaminated groundwater entering the home through a sump; or soil vapor intrusion in winter when use of a heating system creates a negative pressure in the home, drawing VOC vapors into the home. **Ventilation of the building should be minimized in the twenty-four hours prior to and during sampling.**

Many variables can influence indoor air sampling, including air exchange rates, operation of the building HVAC system, hydrogeologic and meteorological conditions, and household activities and chemical usage. All of these variables combine to create site-specific exposure conditions that must be considered in evaluating the indoor air sample results from a home (complete the Residential Indoor Air Sampling Form). To account for these variations, the following measures shall be taken:

- Perform "living area" sampling in a room that is used regularly in the lowest level of the home suitable for occupancy, such as a living room, den, or playroom.

- Avoid kitchens, and laundry rooms where use of personal products and other chemical products may interfere with sampling.

- Close windows and outside doors and keep them closed as much as possible during sampling, except for normal entry and exiting.

- Place indoor samplers on stands approximately 1 meter above the floor in a central part of the room away from heaters, heating vents, high humidity, exterior walls, drafts (vents, open doors and windows, air conditioners, fans) and other obstructions to air flow.

- Place the "source area" sampler near the spill/release (most likely in the basement) approximately 1 meter above the floor.

- All sampling equipment should be placed away from family traffic patterns and out of reach of pets and children.

- Only operate air conditioning units that recirculate interior air.

- Samplers should not be placed close to attached garages, ash trays, or other possible petroleum constituent sources that might provide results that do not reflect contamination related to the spill/release.

- Remove or tightly seal obvious indoor sources of petroleum constituents and other VOC sources during indoor air sampling such as, fuels, paints, cleaning solvents, and mothballs.

- Document household characteristics, resident activities and potential ambient sources that may influence indoor air sampling results on the "Residential Indoor Air Sampling Form".

- Sketch sampling locations.

The residents of the home should be given the instructions listed below to follow 24 hours prior to and during the sampling event:

- **Do not** open any windows, fireplace openings or vents.
- **Do not** operate ventilation fans unless special arrangements are made.
- **Do not** smoke in the home.
- **Do not** use paints or varnishes.
- **Do not** use wood stove, fireplace or auxiliary heating equipment, e.g. Kerosene heaters
- **Do not** operate or store automobiles in an attached garage.
- **Do not** store containers of gasoline or oil within the house or attached garage (except for fuel oil tanks).
- **Do not** clean or polish furniture or floors with petroleum or oil-based products.
- **Do not** use air fresheners or odor eliminators.
- **Do not** engage in hobbies that use materials containing VOCs
- **Do not** use cosmetics including hair spray, nail polish, nail polish removers, etc.
- **Do not** apply pesticides.

Quality Control/Quality Assurance

Follow the manufacturer's guidelines for use of sampling equipment and holding times.
Field blanks, trip blanks and duplicate samples should be kept with and submitted with the samples.
Analyze samples as soon as possible after sampling.
Record general weather conditions during sampling, including ambient temperature.
Maintain chain-of-custody forms.